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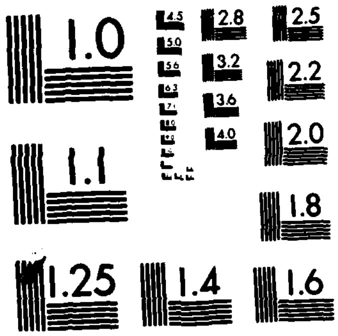

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Report USAFSAM-TR-83-46

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YELLOW OPHTHALMIC FILTERS IN THE VISUAL ACQUISITION OF AIRCRAFT

Wayne F. Provines, Lieutenant Colonel, USAF, BSC
Alton J. Rahe, M.S.
Michael G. Block, Captain, USAF, BSC
Tomasina Pena, Airman First Class, USAF
Thomas J. Tredici, Colonel, USAF, MC

December 1983

Final Report for Period April 1982 - July 1982

Approved for public release; distribution unlimited.

USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas 78235

NOTICES

This final report was submitted by personnel of the Ophthalmology Branch, Clinical Sciences Division, USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks Air Force Base, Texas, under job order 7755-24-01.

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The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

Wayne F. Provines

WAYNE F. PROVINES
Lieutenant Colonel, USAF, BSC
Project Scientist

Thomas J. Tredici

THOMAS J. TREDICI
Colonel, USAF, MC
Supervisor

Royce Moser, Jr.

ROYCE MOSER, Jr.
Colonel, USAF, MC
Commander

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Twenty subjects made a total of 400 threshold visual acquisitions of T-38 aircraft approaching from 9 miles out. Half of the acquisitions were made with the subjects wearing yellow ophthalmic filters, and the other half without filters. The researchers found no overall statistically significant difference in acquisition performance due to the use of yellow filters.

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Wayne F. Provines, Lt Colonel, USAF, BSC	(512) 536-2745	USAFSAM/NGOP

CONTENTS

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YELLOW OPHTHALMIC FILTERS IN THE VISUAL ACQUISITION OF AIRCRAFT

BACKGROUND AND PURPOSE

The yellow ophthalmic lens continues to be popular for use in haze and snow environments. Yellow lenses are used in an attempt to increase target acquisition performance, or to enhance subtle contour differences in border detection tasks. Many U.S. Air Force aircrew members believe yellow lens wear contributes to early detection of distant aircraft in good visibility as well as in marginal visibility.

Visual detection enhancement is needed to give fighter aircrews maximum visual advantage in air-to-air combat and to aid in avoidance of midair collision. The purpose of our effort was to determine if the yellow ophthalmic filter enhanced visual threshold acquisition of approaching aircraft targets.

METHOD

Accurately reproducing target and background information, displayed in a dynamic air-to-air visual search task, is a formidable task. To avoid omitting (or inducing) some essential visual stimulus presented by an approaching aircraft, we chose not to use a simulated target. Rather, we designed a protocol presenting approaching aircraft as visual targets. Maximum experimental control was employed for the operational field study, which was conducted at the Randolph Air Force Base Auxiliary Field, Seguin, Texas. This field is used for touch-and-go landing practice by instructor and student instructor pilots flying T-38 aircraft. Straight-in approaches are made at a 130° (ESE) heading. The approach terrain is essentially flat, without major obstructions. Our experiments began in April 1982 and ended in July 1982. Weather conditions ranged from clear to heavy overcast. Visibility was always good. Testing in marginal visibility would have been desirable; however, flight safety factors obviously precluded such testing. (A quantitative summary is presented in Appendix A.) Testing was done from approximately 1100 to 1500 hr.

Visual acquisitions were made by pairs of subject observers, seated in the front seat of a 1978 Concord automobile (American Motors Corporation), facing the direction of approaching aircraft. This location was near the runway supervisor unit (RSU), approximately 100 yd perpendicular to the aircraft touchdown point on the runway.

The experimental procedure was as follows: On a given day, two subjects were tested simultaneously. One subject wore yellow lenses, plano, or prescription if required. The other subject wore no glasses, or wore clear corrective lenses if required. A cardboard divider separated the subjects. Upon the straight-in approach of an aircraft at approximately 9 miles out, the RSU controller, by earphone communication, would alert the experiment monitor in the rear seat of the automobile. The monitor would simultaneously start three

electronic timers and instruct the subjects to begin visual search for the aircraft. Upon sighting the aircraft, each subject would press a silent control switch, stopping only his timer. No other subject action was permitted that might alert the other subject to the sighting. The third timer was stopped by the monitor as the aircraft passed perpendicular to the automobile. Along with the time of day, acquisition times--to the nearest hundredth of a second--were recorded in the record book. The subjects then alternated eyeglasses and the procedure was repeated. Weather conditions, visibility estimates, and sky luminance--taken near the aircraft observation location--were recorded each half hour. Aircrews were instructed not to use landing lights on days of testing.

Twenty subjects (13 males and 7 females), from 21 to 52 years old, were paired according to age. Visual screening was done on an Armed Forces Vision Test Apparatus (VTA-ND). Subjects were required to read at least 20/20 uncorrected, or corrected if required, in each eye. Those requiring corrective lenses were refracted to best visual acuity. Distance phorias could not exceed 5 prism diopters exophoria, 9 prism diopters esophoria, or 1.5 prism diopters vertical phoria. All subjects passed stereopsis to 15 sec of arc, and passed the American Optical Company's pseudoisochromatic plates color vision test.

Each subject pair observed 20 flights, so each subject of the pair observed 10 flights through yellow lenses, and 10 flights without lenses or through clear corrective lenses.

Yellow lens blanks, procured from the Coburn Optical Company, were fabricated in the Optical Research Laboratory, USAF School of Aerospace Medicine, to fit the HGU-4/P aircrew frame. Maximum prescription tolerance was ±0.125 diopter, 1° cylinder axis. Plano powers were provided in yellow for subjects not requiring corrective lenses. Presented in Appendix A (Figs. 1 and 2) are the spectrophotometric curves and x,y color coordinates for yellow ophthalmic lenses and the automobile windshield, respectively and in combination.

RESULTS

For the "first arrangement," one person in each pair of subjects was randomly chosen to wear the yellow lenses first (while the second subject wore the clear lenses). For the "second arrangement," the second subject wore the yellow lenses (while the first subject wore the clear lenses). Each arrangement was used during 10 flights.

For each pair and flight, the difference was calculated for the clear minus yellow lens sighting time. Since one subject in each pair would tend to be better at sightings, these differences were averaged over the 20 sightings (10 for each arrangement) to eliminate the "better subject" effect. This average difference (DIFF) then contained only the effect of the lens difference. A Student's t-test was performed on the DIFF values from the 10 pairs of subjects, testing the null hypothesis of no lens difference in the time required to observe the approaching aircraft. The overall mean DIFF was 2.10 sec and, generally, the variability was large among the pairs. No statistical evidence

of a difference between the yellow and clear lenses was observed. A summary of the DIFF values is presented in Table 1.

Also shown in Table 1 is the summary of the algebraic sign of the differences for each flight-subject pair, summed over both arrangements. For only one pair did the proportion (yellow better than clear) differ significantly from p=.5.

TABLE 1. CLEAR LENS MINUS YELLOW LENS DIFFERENCE VALUES (SEC)

Subject pair	Difference	Sign of difference +	Sign of difference -
1-2	-1.47	8	12
3-4	-4.26	10	10
5-6	5.67	11	9
7-8	1.80	10	10
9-10	10.18	13	7
11-12	10.94	16	4*
13-14	0.01	11	9
15-16	-3.94	11	9
17-18	2.53	10	10
19-20	-0.45	9	11

*$p<.05$

In addition, two transformations of the data were analyzed:

a. ratio of the "clear" time to "yellow" time; and

b. this ratio expressed in logarithmic (log) units.

An outlier detection procedure by Grubbs and Beck (1) detected several outliers in the ratio variable. The outliers were removed before the statistical analysis. When testing the observed ratio mean (1.15) against an hypothesized value of 1, no statistical difference was found. The log of the ratio was tested against an hypothesized value of zero, and no statistical difference was found.

To determine if any of the subjects' performances were enhanced or degraded by yellow lens wear, a Student's t-test was used to compare the 10 sightings (touchdown times minus time plane spotted) while subjects wore yellow lenses, with the 10 sightings while subjects wore clear lenses. Significant differences were detected only for subjects 2 and 11. Subject 2 observed the aircraft earlier with clear lenses than with yellow ($p<.05$). Subject 11 observed the aircraft earlier with yellow lenses ($p<.05$). The performance differences of these two subjects is unexplained.

DISCUSSION

To date, few research studies have shown improved visual performance by use of selective waveband filters. Yet, for a number of reasons, controversy continues over their usefulness.

Many pilots are absolutely convinced that yellow lens use improves their target acquisition performance (2, 3, and 4). Simply to dismiss such claims by a group whose visual capabilities are crucial to the mission task, and often to survival, seems unwise. Results of yellow lens effects on the contrast sensitivity function vary (Appendix B). In several studies, minimally increased sensitivity in the mid or low spatial frequencies have been shown (5, 6, 7, and 8). In at least one study, no consistent difference in contrast thresholds with yellow filter use was found (9). Recently, investigators have reported that yellow lenses significantly increase contour and depth perception performance under specific laboratory and snow-covered terrain conditions (6, 8, and 10). Finally, many selective waveband filter studies have been negative or inconclusive due to inadequate field experimental control or insufficient data.

Recent vision research is providing information which suggests that yellow filters may reduce the inhibitory blue input in the chromatic visual channels, and thus increase the neural signal (6 and 8). This effect appears to occur with low-contrast targets in the intermediate frequency ranges only. Such results agree rather well with reports of no improvement in high resolution acuity (high spatial frequencies) tasks, but of enhancement of depth and contour detection performance (low or intermediate frequencies). Ambient luminance may also play some role.

On straight-in approaches, T-38 aircraft follow a similar glide slope at 155 ± 20 knots. The mean acquisition distance for all subjects in this study was 4.55 mi. At 4 mi from touchdown, the aircraft visual angle was about 1 min of arc horizontal by 2 min of arc vertical. (Refer to Appendix A for calculation.)

Visual acquisition of aircraft is a minimal target-detection task. Upon acquisition, an aircraft subjectively appears as an indistinct dark circular spot. The contrast and frequency content of the target has yet to be fully determined. If the 1-min x 2-min arc target is averaged to 1.5 min overall, the frequency distribution is mainly in the 20 cycles/degree range, with some lower frequencies included. Because yellow filters are reported to be ineffective above 8 cycles/degree, the fact that yellow lens use did not aid acquisition performance for the targets presented in this study may not be surprising.

Poor visibility conditions, reducing acquisition distances, may increase the angle of aircraft subtend to equate to moderate frequency ranges. We are tempted to speculate that, in such conditions, yellow lens use may increase the visual signal and thus enhance acquisition performance.

To date, neither a fully developed theory nor field vision performance data are available upon which to recommend yellow lens use for airborne vision

tasks. Nevertheless, some physiological basis may yet be responsible for the popularity of yellow lens wear.

In summary, the results of this effort indicate that yellow lens wear neither enhances nor degrades visual acquisition performance for detection of approaching aircraft under high-ambient illumination and good visibility conditions.

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6. Kinney, J. A. S., C. L. Schlichting, D. F. Neri, and S. W. Kindness. Various measures of the effectiveness of yellow goggles. NSMRL-941. Naval Submarine Medical Research Laboratory, Oct 1980. [Refer to Appendix B, p. 19.]

7. Richards, W. A. Colored filters as factors in improving human visual acuity. USAF AMRL-TR-73-100. USAF Aerospace Medical Research Laboratory, Sep 1973. [Refer to Appendix B, p. 20.]

8. Kinney, J. A. S., C. L. Schlichting, D. F. Neri, and S. W. Kindness. Reaction time to spatial frequencies using yellow and luminance-matched neutral goggles. Am J Optom Physiol Optics 60(2):132-138 (Feb 1983).

9. Ginsburg, A., and M. Nelson. Visual acuity with colored filters. Technical Memo, USAF AMRL/HEA. USAF Aerospace Medical Research Laboratory/HEA, May 1978.

10. Schlichting, C. L., S. M. Luria, J. A. S. Kinney, D. F. Neri, and S. W. Kindness. Aids for improving vision in white-out. NSMRL-937. Naval Submarine Medical Research Laboratory, Aug 1980. [Refer to Appendix B, p. 21.]

A P P E N D I X   A:

SKY CONDITIONS, AIRCRAFT SUBTEND, AND TRANSPARENT MEDIA DATA

APPENDIX A:

SKY CONDITIONS, AIRCRAFT SUBTEND, AND TRANSPARENT MEDIA DATA

Descriptive statistics for sky luminance and visibility. Luminance was measured by a Spectra brightness spot meter. Visibility was estimated by the Runway Supervisory Unit controller.

Variable	Minimum	Maximum	Mean
Foot Lamberts	1500	15,000	4760
Visibility (in miles)	7	25	15.2

Frequency of weather conditions as determined by the experiment monitor:

Weather conditions	Number of flights	Percent of total
Sunny - clear	42	21%
Hazy sunshine	66	33%
Partly cloudy	40	20%
Cloudy - overcast	52	26%

Calculation for aircraft visual subtend:

At 4 mi from touchdown, aircraft altitude is about 500 ft, thus resulting in a line-of-sight angle from the horizon of 2.71°. Aircraft pitch angle here is 3-5° nose up. The T-38 is 50 ft long, with a maximum fuselage width of about 6 ft at the engine pods. The maximum vertical fuselage dimension at the canopy is about 5 ft. The aircraft underside, seen due to the pitch angle, adds another 6.7 ft in apparent vertical height. The maximum visible head-on profile is therefore about 6 x 12 ft. The visual angle of the T-38 at 4 mi is about 1 x 2 min of arc maximum horizontal by vertical. Maximum fore-aft wing dimension is about 9 ft. Maximum pitch angle would result in an apparent wing thickness of 1.2 ft. While we doubt that the wings would add to the profile at this distance, the 25-ft wingspan would double the horizontal subtend to 2 min of arc.

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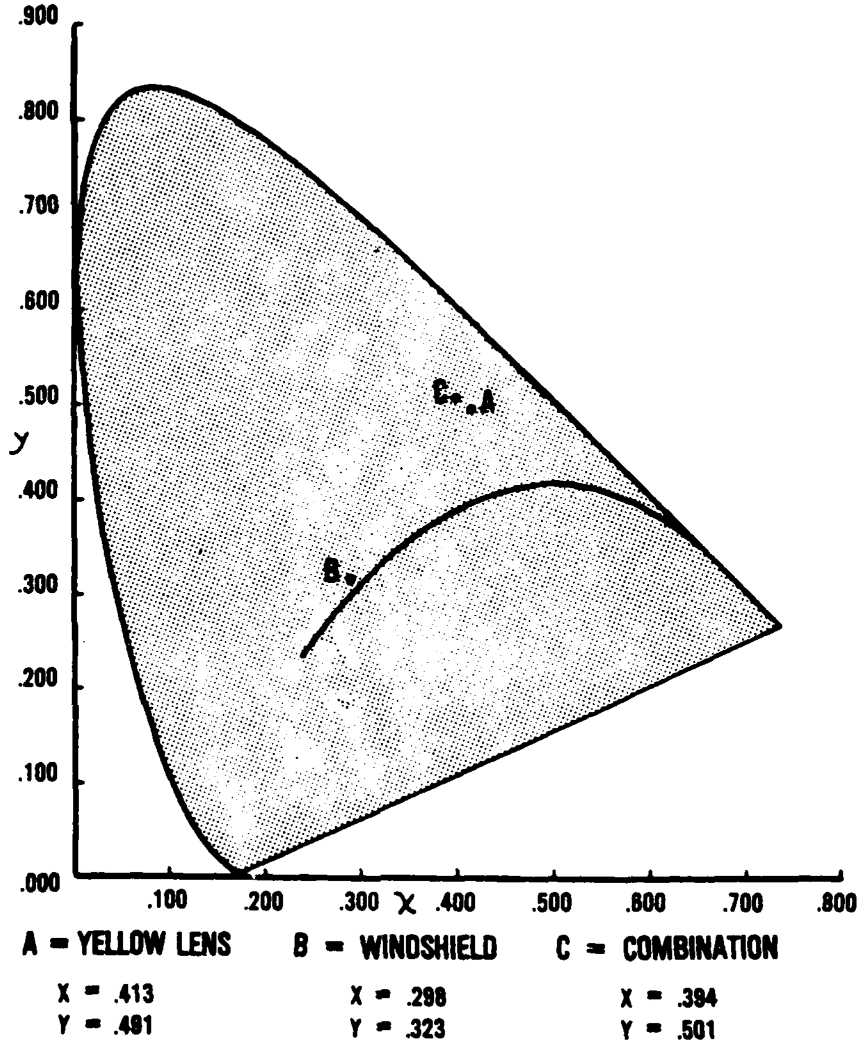

Figure 1. The x,y chromaticity values for yellow ophthalmic lens and automobile windshield, respectively and in combination.
A Prichard 1980 B Spectroradiometer was used to ascertain the above values. (Windshield section measured was replacement sample of same manufacturer.)

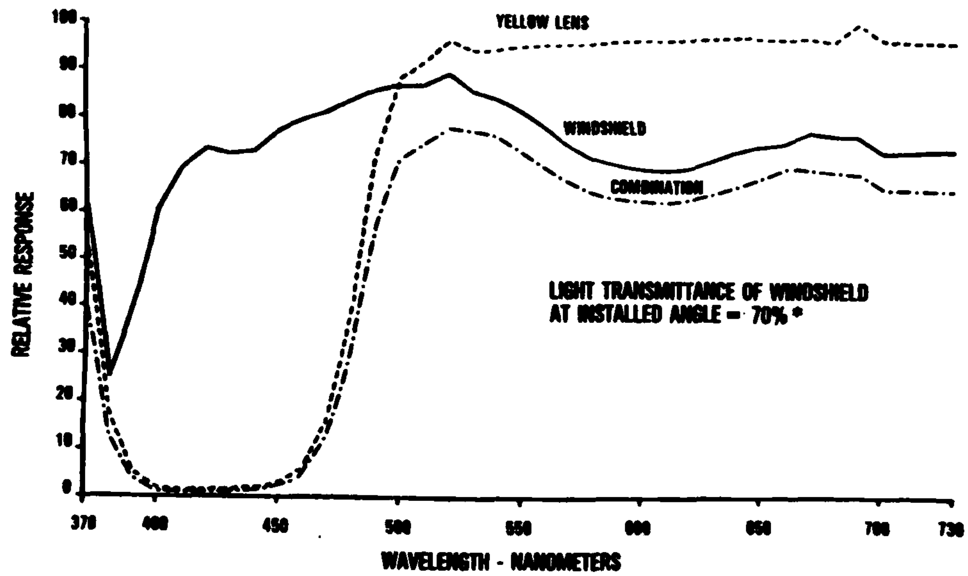

Figure 2. Transmittance of yellow ophthalmic lens and automobile windshield, respectively and in combination. A Prichard 1980 B Spectroradiometer was used to ascertain the above data. (Windshield section was a replacement sample of the same manufacturer.)

A P P E N D I X B:

ANNOTATED BIBLIOGRAPHY

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APPENDIX B:

ANNOTATED BIBLIOGRAPHY

Everson and Levene included in their report USAF AMRL-TR-73-13 (Ref. 5, p. 7), an annotated bibliography of research related to selective waveband filters:

Everson, R. W.
Levene, J. R.

COMPARATIVE PERFORMANCE OF AVIATION FILTERS ON THE HUMAN CONTRAST SENSITIVITY FUNCTION

AMRL-TR-73-13, Jul 73

Grating targets of different spatial frequency and with square and sine wave luminance distributions were presented to male subjects who wore ophthalmic filters that are frequently used by aviators; namely, neutral gray, yellow, and rose-colored. Threshold light modulation that permitted detection of the grating pattern was determined. Average luminance levels from bright to dim were used. Although contrast sensitivity was found to vary with luminance level, it has not been possible to demonstrate the clear-cut superiority of one colored sunglass filter over another in this experiment. The differences that are seen are related to the luminous transmittances of the filter and not to their intrinsic colorations.

We have assembled the following supplementary references which are limited to research addressing filter effects on target acquisition performance. While the references may not be complete, we trust that they will be of interest to persons working in this field.

Borswaldt, B.
Fishman, G. A.
Vander-Melven, D.

SPECTRAL TRANSMISSION CHARACTERISTICS OF TINTED LENSES

ARCH OPHTHALMOL 1981, 9912 (293-297)

A total of 90 prescription and commercially available tinted lenses were evaluated for spectral transmission characteristics. An inappropriately large number of these lenses transmitted unnecessarily high amounts of light in the near ultraviolet, visible, and near infrared portions of the spectrum. No criteria regarding lens composition, color, or cost could reliably predict the effectiveness of individual lenses.

<u>NOTE</u>: Throughout this Appendix, abbreviations have been used for the USAF Aerospace Medical Research Laboratory (AMRL) and for the Naval Submarine Medical Research Laboratory (NSMRL).

Hart, R. S. EFFECT OF COLORED LENSES ON VISUAL PERFORMANCE

AMRL-TR-74-78, Jul 74

This study compares operator target detection performance while wearing red, yellow, and gray sunglass lenses, and during unaided viewing. A research task was performed outdoors using survival orange targets located at ranges of 1600 ft to 4500 ft from the subjects. No statistically significant performance differences were obtained, although subjectively the operators preferred the yellow lenses over the gray sunglasses and unfiltered conditions.

Heckart, S. A.
Hanavan, E. P.
Porterfield, J. L.
Self, H. C.
McKechrue, D. F.

AIRBOURNE VISUAL RECONNAISSANCE WITH YELLOW SUNGLASSES

AMRL-TR-71-36, Jun 71

The study investigated airbourne visual reconnaissance with and without yellow sunglasses under conditions of moderate haze and high ambient, midday illumination. One group of five observers wore Bausch and Lomb Kalichrome C yellow glasses. A second group of five observers did not wear yellow glasses. The observers searched from the side scanner stations of a B-50 aircraft for tactical target sites located on rolling farm and woodland terrain. The aircraft flew at 180 knots ground speed, 3500 ft above the ground. The mean percent of target sites detected by both the group that wore yellow glasses and the group that did not was 69 percent. For the sites detected, the group with yellow glasses identified 55 percent of the targets; the group without yellow glasses identified 70 percent. Because of large within-group variance, this difference was not statistically significant. Thus, this study found yellow sunglasses to be of no value as an aid to visual reconnaissance in an area search task under conditions of high ambient illumination and moderate haze.

Kinney, J. A. S.
Schlichting, C. L.
Neri, D. F.
Kindness, S. W.

REACTION TIME TO SPATIAL FREQUENCIES USING YELLOW AND LUMINANCE-MATCHED NEUTRAL GOGGLES

AM J OPTOM PH[illegible] OPTICS 1983, 60(2), 132-138

The populari[illegible] w goggles for outdoor activities has long been a paradox to visua[illegible] s as previous tests of their effectiveness have failed to show any vi[illegible] antage. The achromatic/chromatic theory of color vision suggests a possible solution to the paradox which was tested by measuring reaction times to spatial frequencies of varying contrast. Reaction times were faster with yellow goggles than with luminance-matched neutrals under certain conditions. These conditions included frequencies in the middle of the range of human sensitivity and, specifically, the lower contrasts of these frequencies. The theoretical and practical applications of the results are discussed.

Kinney, J. A. S.
Schlichting, C. L.
Neri, D. F.
Kindness, S. W.

VARIOUS MEASURES OF THE EFFECTIVENESS OF YELLOW GOGGLES

NSMRL-941, 8 Oct 80

This paper presents the results of four laboratory studies in which perception through yellow goggles is compared with that of luminance-matched neutral goggles. The measurement of depth perception showed that there were no differences between yellow and neutral goggles for stereo acuity, but that there were significant improvements in the perception of low contrast with yellow over luminance-matched neutral goggles. In addition, the speed of response to large targets was faster with yellow than with neutral goggles.

Luria, S. M.

COLD WEATHER GOGGLES. II. PERFORMANCE EVALUATION

NSMRL-978, 23 Mar 82

The performance of various tasks of importance to the Marines was compared when the subjects were wearing different goggles designed to protect the eyes from the cold. Color perception through yellow goggles and riflery through the most distorted goggles were degraded, but there were no significant impairments in acuity, depth perception, or vision through binoculars. The optical standards adhered to in the manufacture of commercial goggles appears to permit the satisfactory performance of practical tasks.

MacLeod, S.
Hilgendorf, R. L.
Searle, R. G.

EFFECTS OF LENS COLOR ON TARGET VISIBILITY IN AIR-SEA RESCUE

AMRL-TR-74-58, 1974

Visual detection of life rafts in the sea presents a difficult task which might be aided by use of appropriate sunglasses designed to reduce glare and atmospheric attenuation while enhancing target-to-background contrast. To evaluate this possibility, target acquisition performance associated with several types of sunglass lenses was compared with that of the unaided eye. A circular 1:10,000 scale terrain model was used to simulate an air-sea rescue operation under conditions of relatively low daylight illumination. No filter was found to be superior to the unaided eye. The data agree with recent target acquisition studies in showing no advantage for yellow sunglass lenses. The results are also consistent with the assumption that supposed enhancement properties of colored lenses may well be offset by losses in light transmission associated with their use.

Miller, D. THE EFFECT OF SUNGLASSES ON THE VISUAL MECHANISM

SURV OPHTHAL, 1974, 19(1), 38-44

The paper is divided into three sections relating to the incident light: effect on intensity, effect on spectral distribution, and effect on environmental factors which operate on the light. It is concluded that: the lenses should eliminate ultraviolet light; the light transmission factor for tinted lenses used as sun wear should be between 10% and 25%, and for military and aviation use the transmission factor should be between 10% and 16%; the addition of polarizing capacity to sunglass yields an additional benefit, namely, the elimination of certain sources of glare; the actual color of the lens is not important from a vision standpoint, except in the case of the color deficient patient. Here, the color should be pale or gray; those benefiting most from the use of sunglasses are aphakic patients and people who spend long periods on beaches or snowfields and at high altitudes.

Richards, W. A. COLORED FILTERS AS FACTORS IN IMPROVING HUMAN VISUAL ACUITY

AMRL-TR-73-100, Sep 73

When a yellow (minus blue) filter is placed before an observer's eyes, most observers report an increase in brightness of the field viewed. This brightness increase occurs even though the radiant energy reaching the retinas is reduced. The magnitude of the effect is about 25% for filters customarily used for yellow goggles, and is restricted to photopic viewing conditions. This study examines the possibility that there may be a correlated improvement in acuity when the brightness of the field is enhanced by introducing yellow filters. No such improvement in acuity is found if acuity is measured by the threshold contrast needed to detect gratings constructed from sinusoidal modulations of luminance. For spatial frequencies higher than 10 c/deg, however, some observers may suffer a loss in acuity if bluish filters are introduced. Yellow filters neither degrade nor improve sinewave target detection at any spatial frequency from 0.5 to 40 c/deg. When square-wave gratings are used as targets, yellow filters may improve detection for the lowest spatial frequencies (less than 2 c/deg). This improvement in the detection of square-wave gratings appears correlated with the brightness enhancement effect of the yellow filters. The explanation for the contrast-enhancing effect of yellow filters is still in doubt. However, the obvious physical and psychological interpretations can be shown to be incorrect. Instead, the enhancement effect appears to have a physiologic basis involving the nonlinear summation of cone mechanisms in the presence of an edge.

Schlichting, C. L. AIDS FOR IMPROVING VISION IN WHITE-OUT
Luria, S. M.
Kinney, J. A. S.
Neri, D. F.
Kindness, S. W.

NSMRL-937, 13 Aug 80

The ability to see well deteriorates markedly under conditions of uniform visual stimulation (white-out). These conditions are frequently encountered by both Navy and Marine Corps troops operating in winter environments. This study tested two different visual aids in an attempt to improve vision under these conditions. One of the aids, a yellow goggle, showed promise for improving the perception of depth in both low light and snow conditions. The other, a correction for empty field myopia (nearsightedness), did not improve vision. Further research is planned to specify more precisely the conditions in which the yellow goggles improve vision and to investigate the reason for the failure of the lenticular corrections to improve vision.

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